

# Schedule and Cost Growth

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# Background

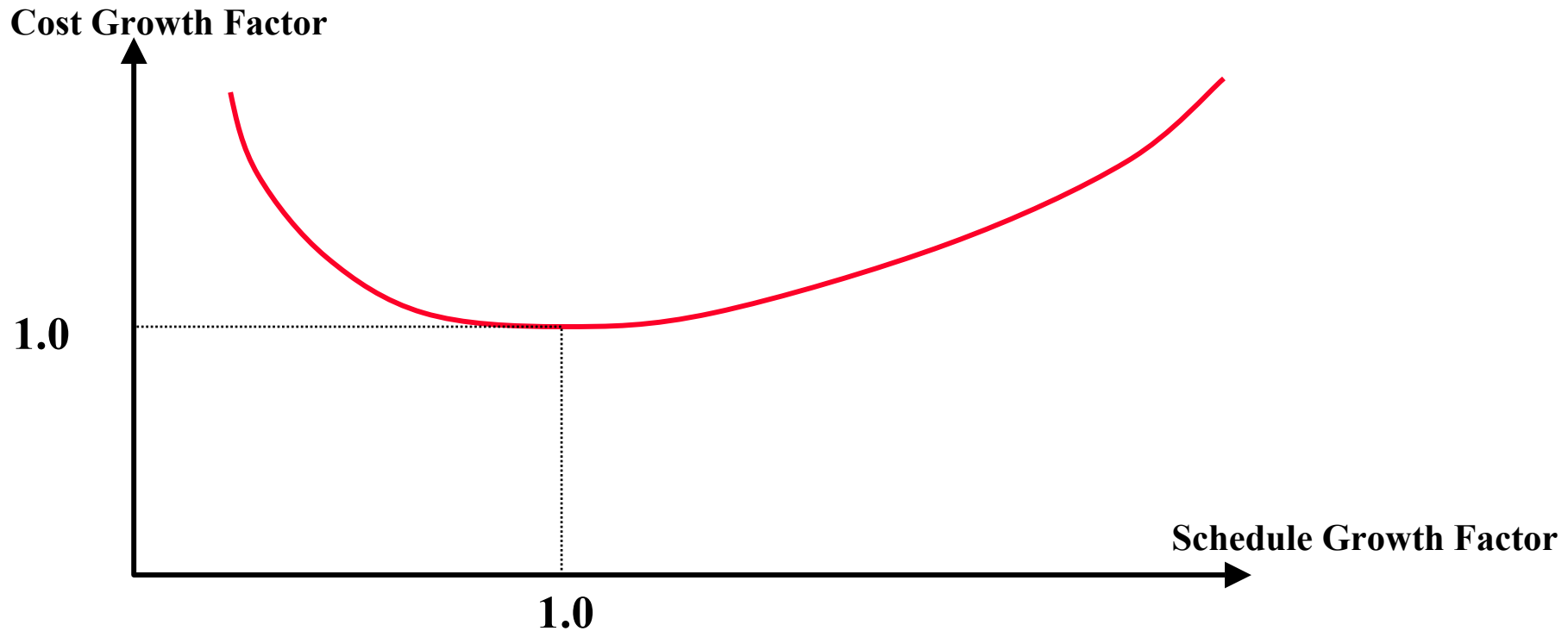
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- **At the BMDO Risk Working Group of 29/30 May 01, Schedule Risk was a major topic**
- **Action Item:**
  - **Investigate Schedule Risk**
    - Content variation
    - *Cost risk\**
    - PERT
    - Time and budget constraints

\* The subject of this paper

# Hypothesis

- Many people believe<sup>1</sup> a graph of cost growth vs. schedule growth as illustrated below:



<sup>1</sup> *Cost Risk Schedule* – CEAC, Dr. M. Anvari,  
First BMDO Cost Risk Symposium, 4 October 2001

# The Data

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- **We analyzed data from the RAND Cost Growth Database with *both* the following characteristics:**
  - **Programs with E&MD only**
    - **Because growth is different for those with and without PDRR**
  - **Programs with schedule data in the requisite fields**
- **There were 59 points. The analysis follows.**

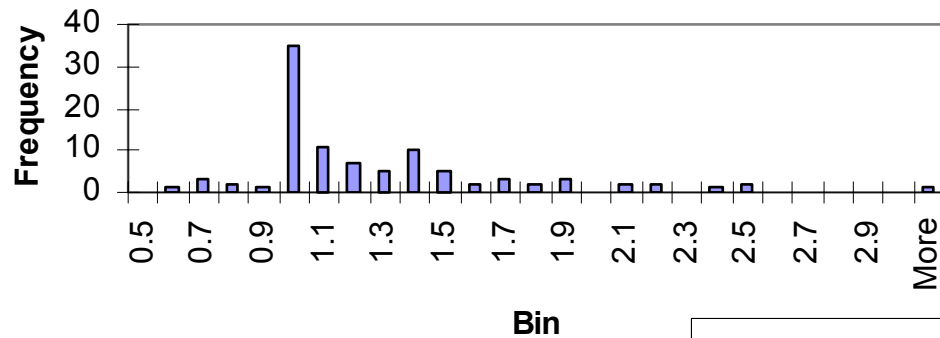
# Descriptive Statistics for Schedule Growth

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- **We will look at these descriptive statistics in the following slides**
  - **Distribution shape**
  - **Scatter plots**
  - **Dollar weighting**

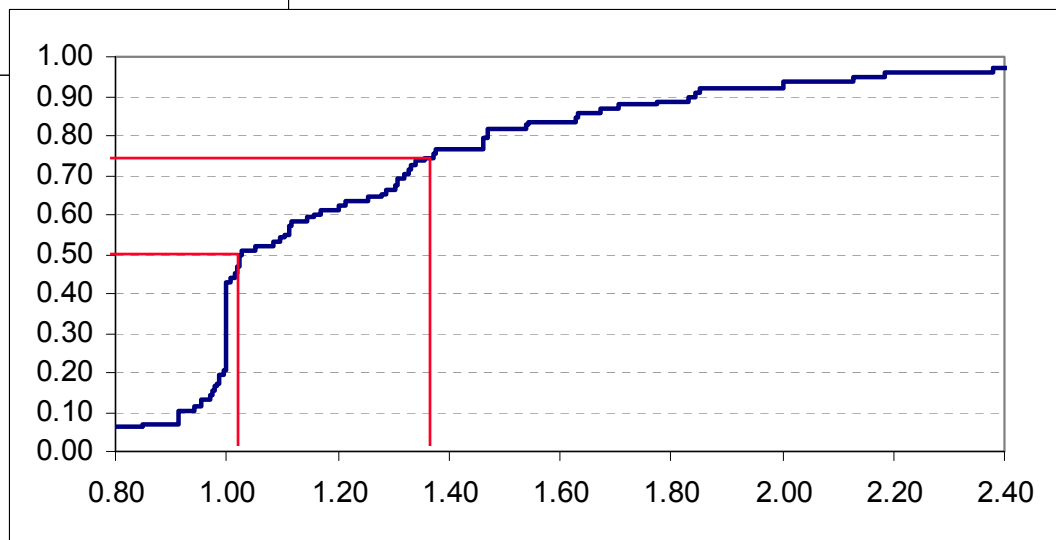
# Schedule Growth Distribution

Phase 2 SGF Histogram



PDF for  
Schedule  
Growth

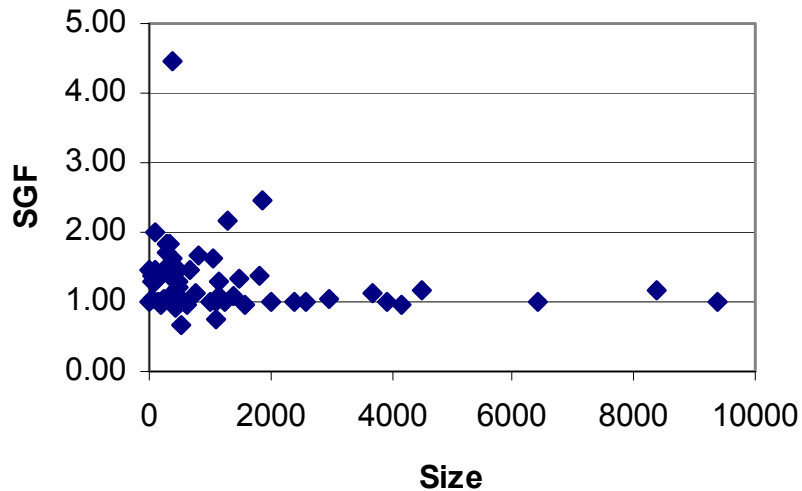
CDF for  
Schedule  
Growth



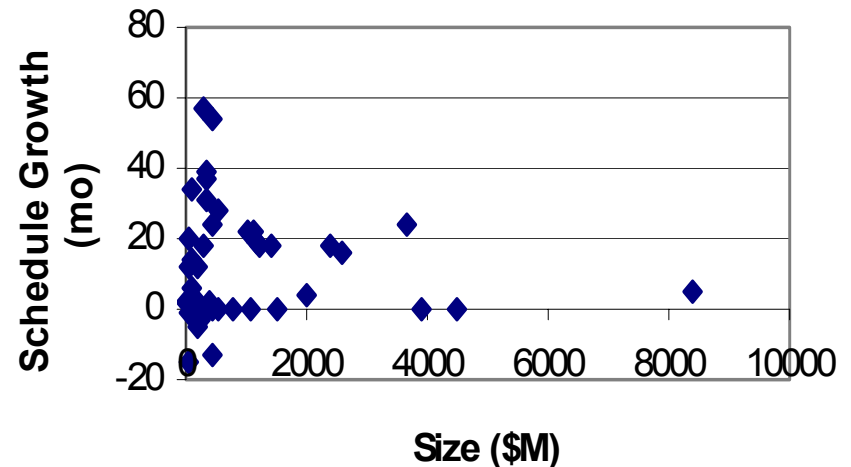
These two graphs look much like the CGF graphs, but the PDF is tighter here, and the CDF is steeper.

# Basic Scatterplots – SGF & Sked vs. Dollar Size

SGF vs Size

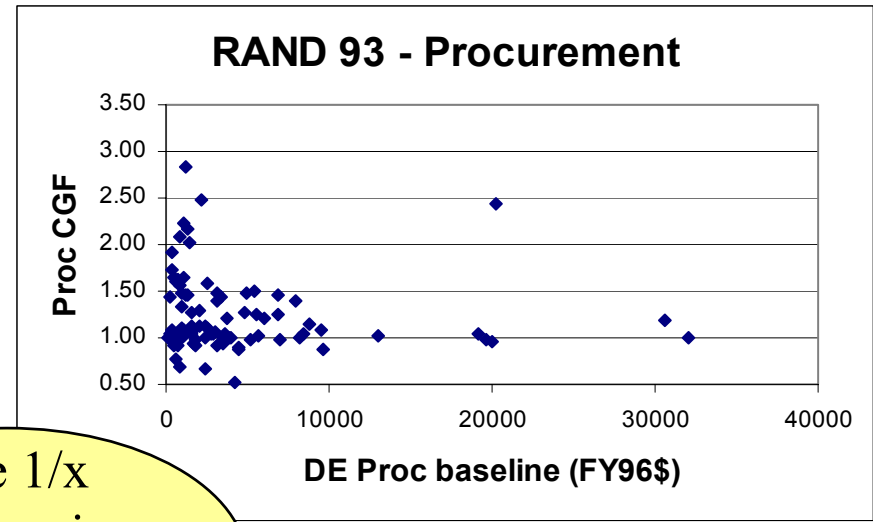
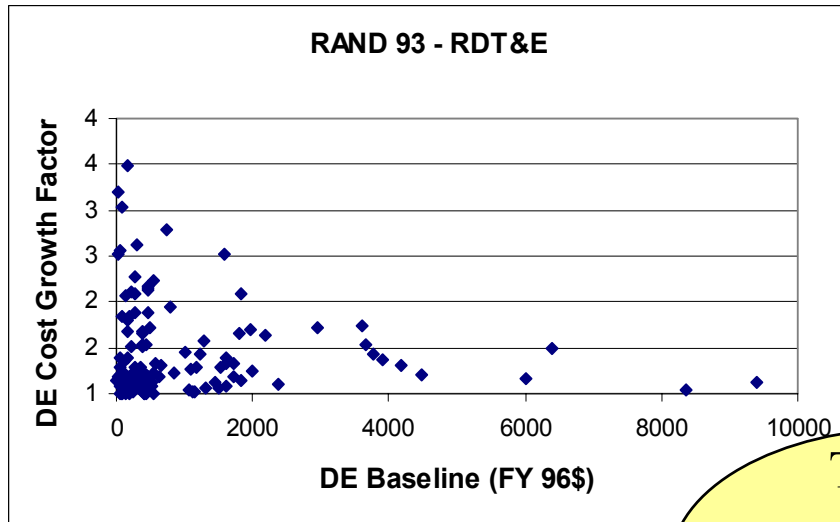


Sked Growth vs Size

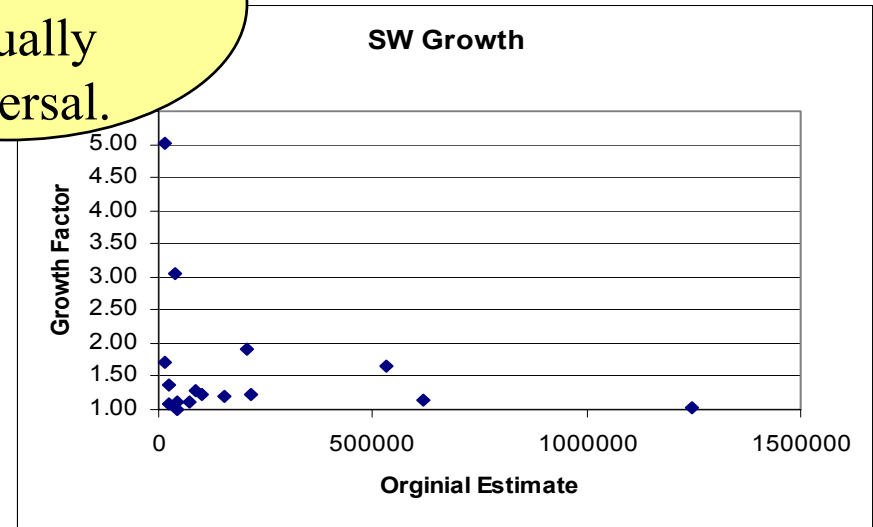
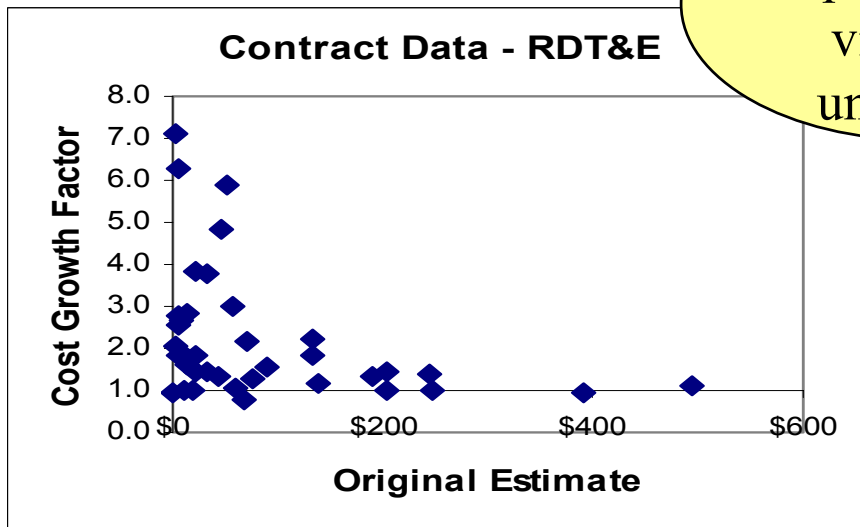


We see the usual size effect, analogous to that in CGF graphs  
Bigger programs have less schedule growth

# The “1/x Pattern”

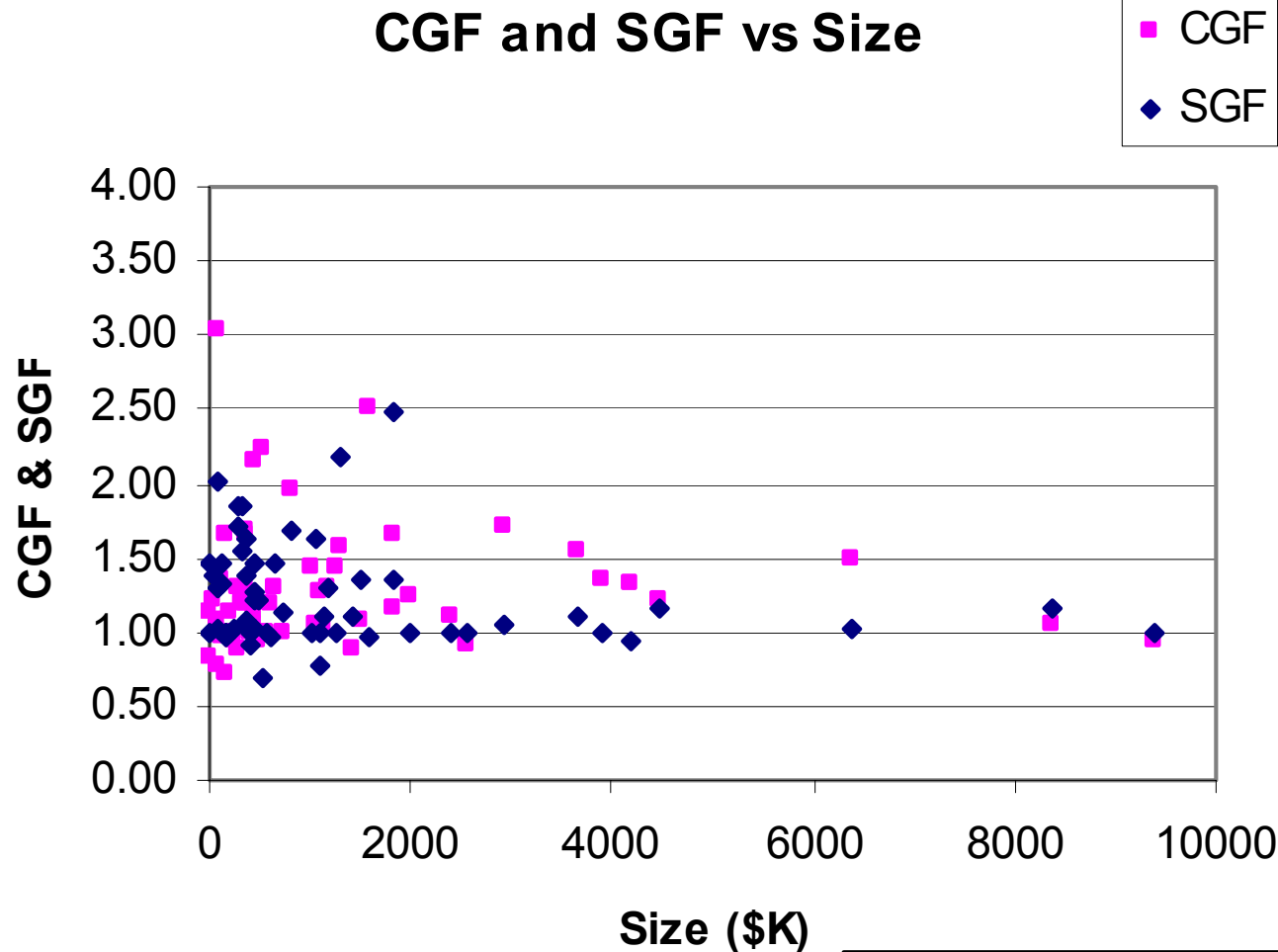


The 1/x  
pattern is  
virtually  
universal.





# CGF and SGF vs. Cost Size

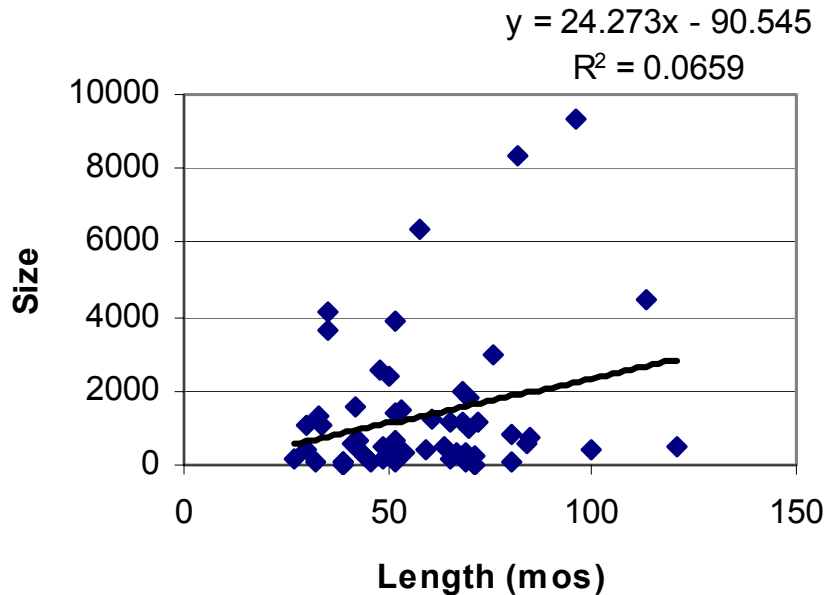


The pattern is similar, but CGF is generally more extreme

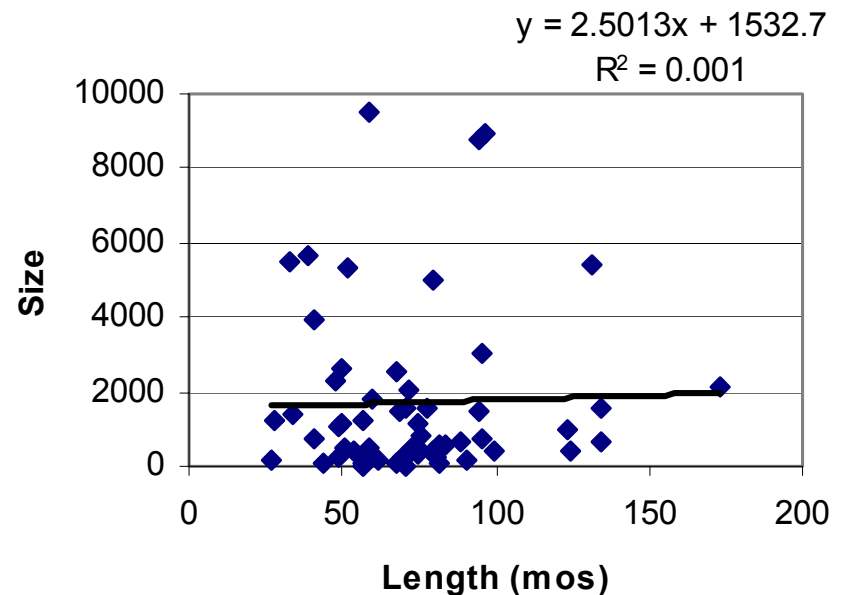
1 Pt Removed for zoom

# Basic Scatterplots – Dollar Size vs. Length

Program Size vs Schedule Length  
Initial



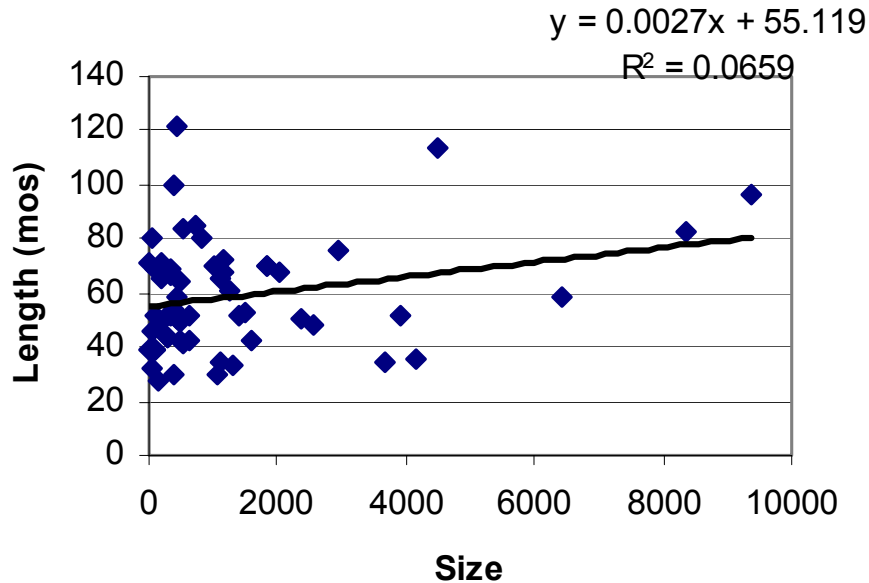
Program Size vs Schedule Length  
Final



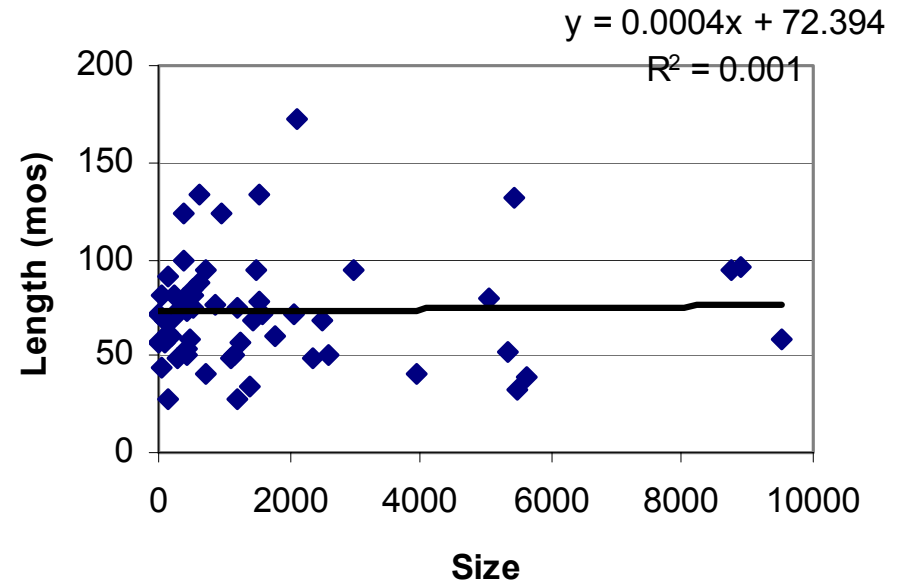
At Phase 2 start, there is a *vague* connection between length and size  
At end, there is *no* connection  
We would not say that longer programs are costlier

# Basic Scatterplots – Length vs. \$ Size

Program Schedule Length vs Size  
Initial

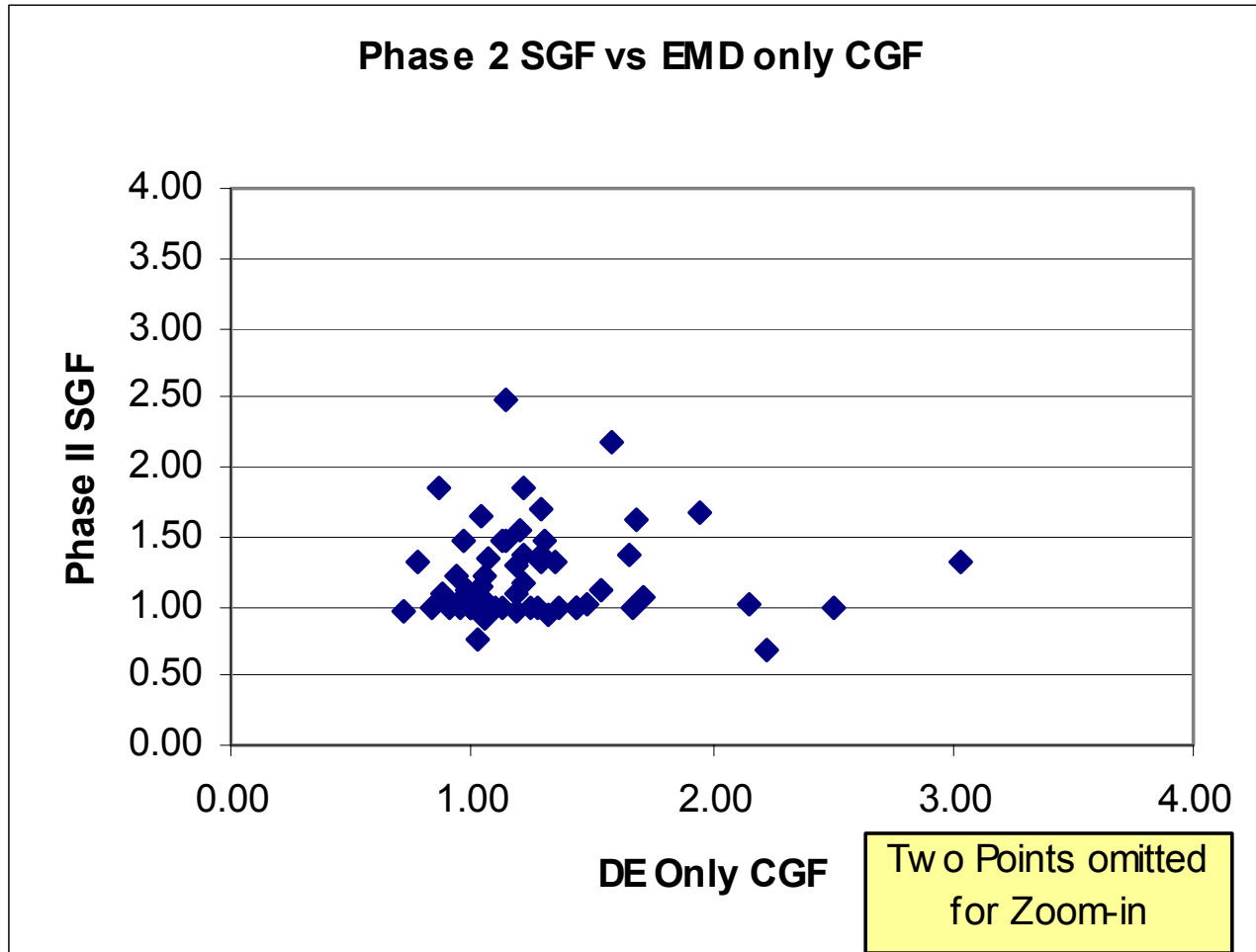


Program Schedule Length vs Size  
Final



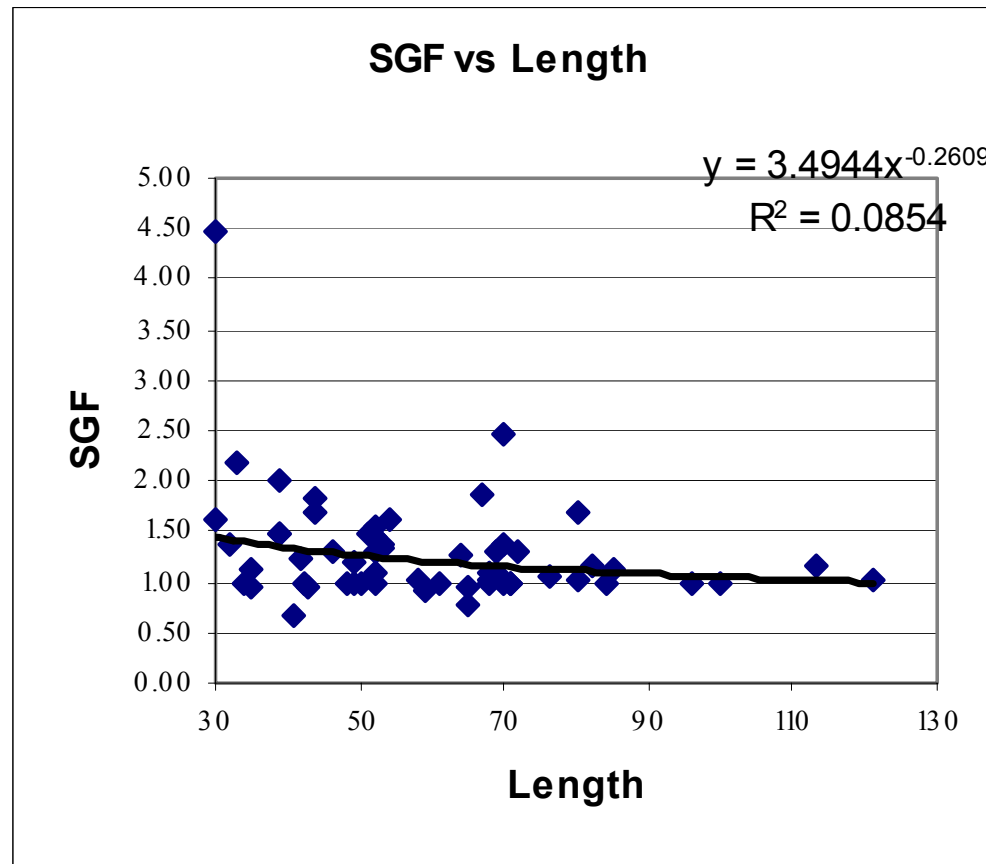
At Phase 2 start, there is a *vague* connection between size and length  
 At end, there is *no* connection  
 We would not say that costlier programs are longer

# Basic Scatterplots – Cost Growth



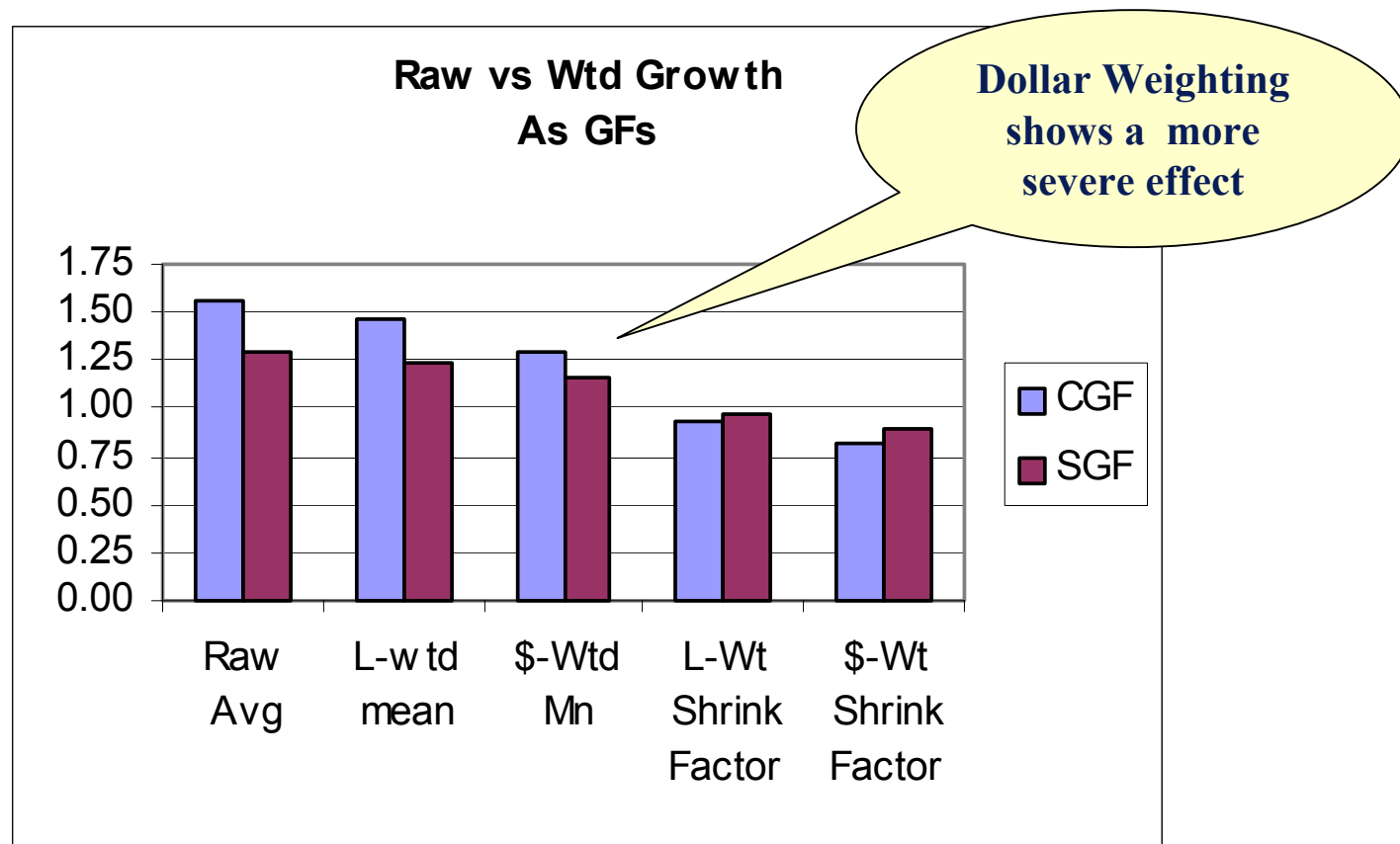
There is no *obvious* connection between CGF and SGF

# Basic Scatterplots - Length



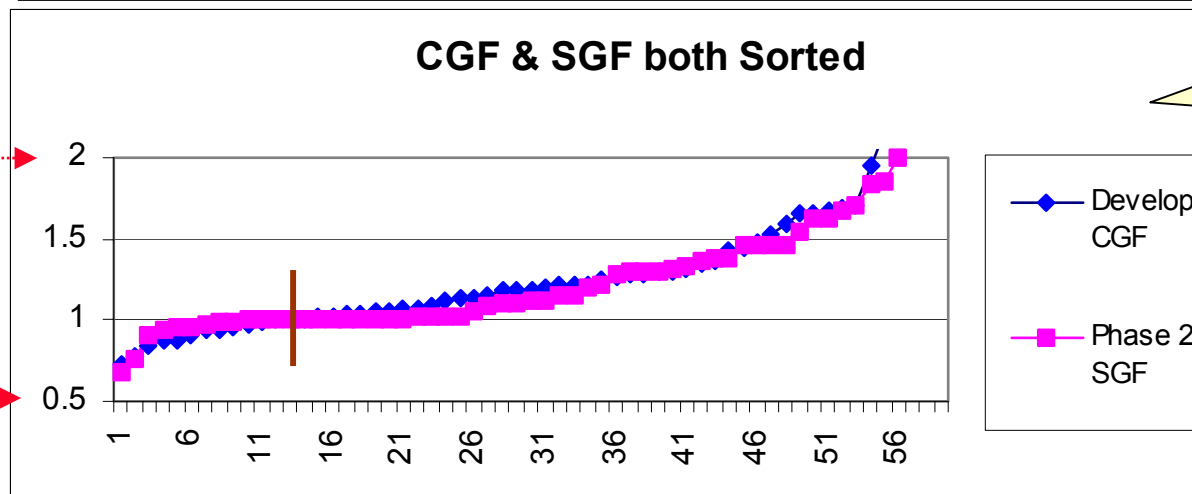
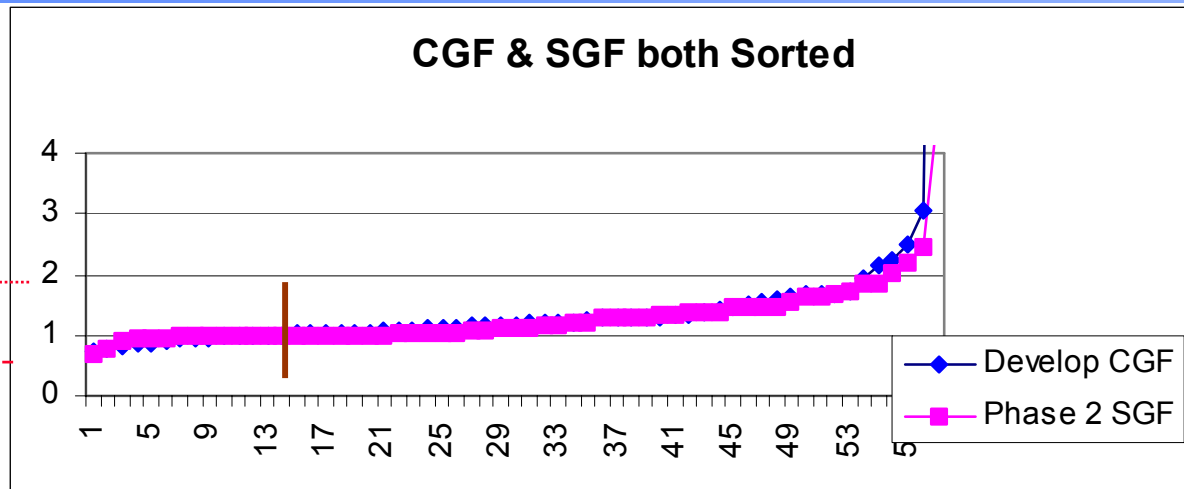
**There is a slight tendency for longer programs to grow less**

# Weighting by Length- and Dollar-Size



**Size growth is less than cost growth**  
**Weighting by Length- and Dollar-Size both reinforce size effects**

# Sorted Graphs

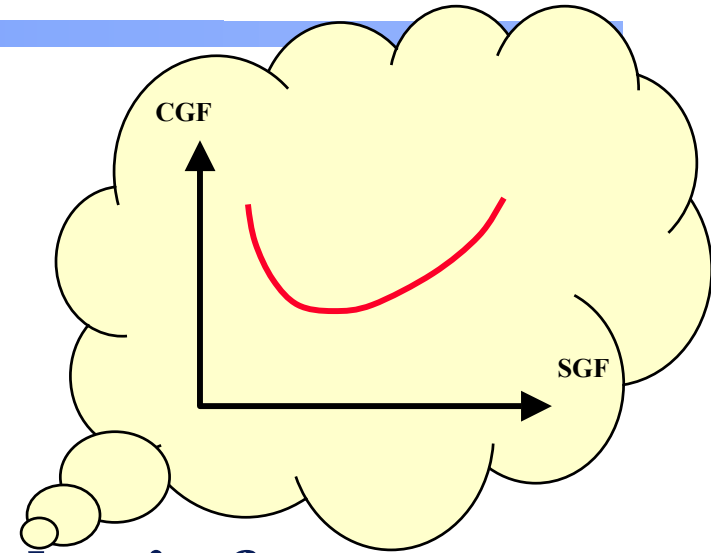


This graph is a zoom-in

**Sorted CGF shows more growth than Sorted SGF**  
 (To the left and right of the **x-intercept**, blue y-values are more extreme)

# Correlation and Other Joint Effects Between Schedule Growth and Cost Growth

- **We will look for correlation**
  - Parametric
  - Non-parametric
  - Trends in sorted data
- **We will investigate the hypothesis for schedule growth vs. cost growth**
  - We will normalize by dollar size to eliminate any inadvertent distortion



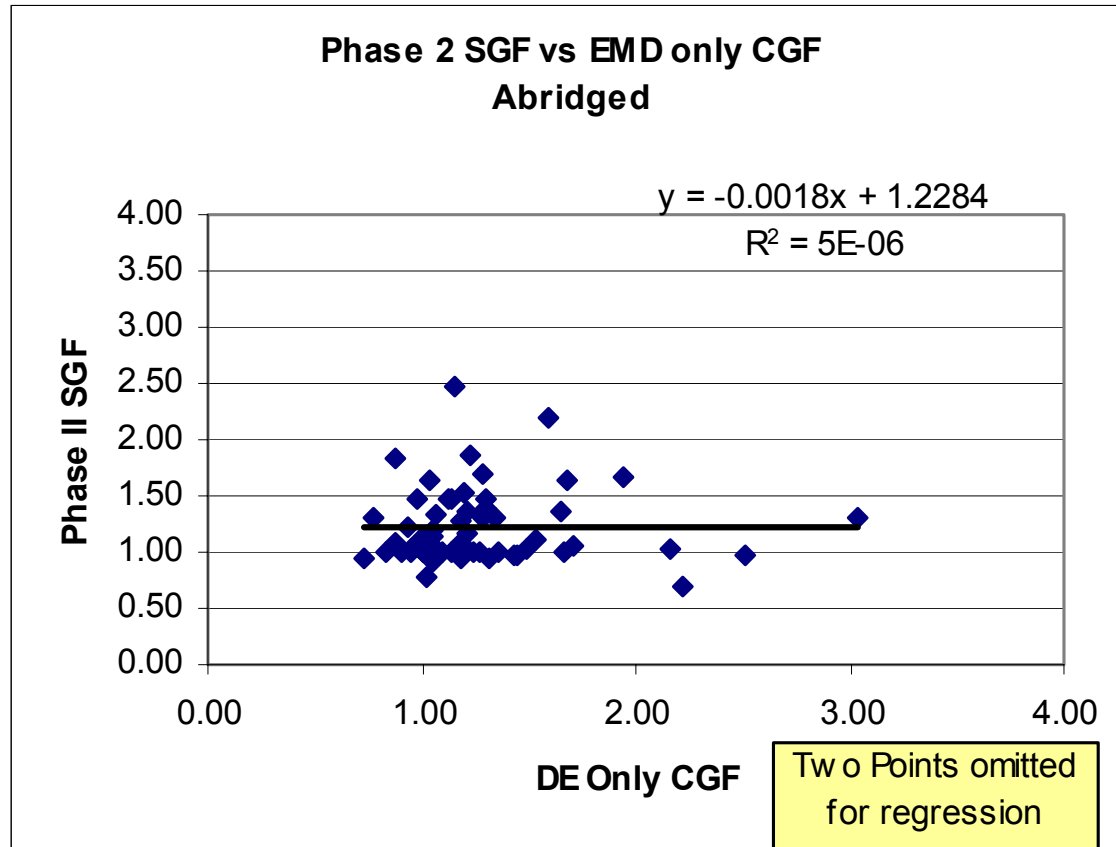


# Correlation of SGF and CGF

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- Is there correlation between size and cost growth, as may be assumed?
- We will perform both a parametric and non-parametric test

# Correlation - Parametric



**There is no parametric correlation**

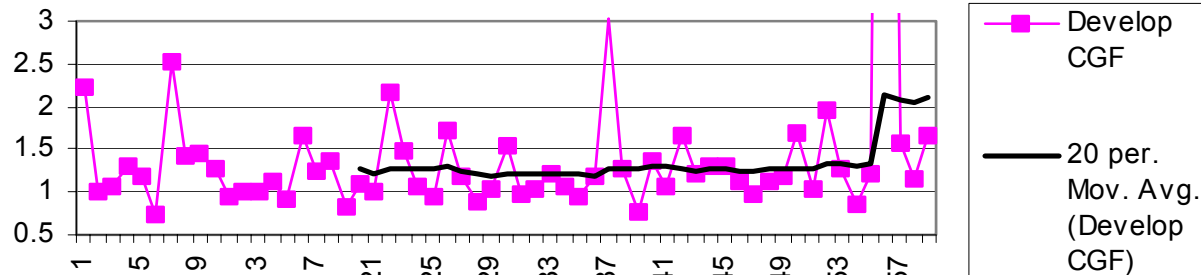
# Correlation – Non-Parametric

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- **Test**
  - ***Cox Stewart Test for Trend*** test statistic of 18 is within the critical values of 8.41 and 18.59
    - The non-parametric test cannot reject no correlation
    - Used CGF Sort because CGF had less ties, thus less ambiguity
  - **Previous parametric test cannot reject no correlation**
  - **Moving averages of CGF do not show a rise**
- **Conclusion: Cannot reject “no correlation”**
- **Visual presentations follow**

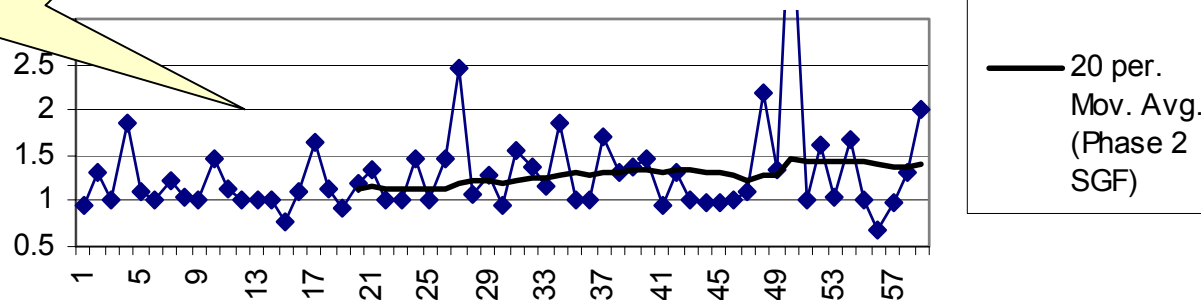
# Patterns in SGF and CGF

CGF after SGF Sort

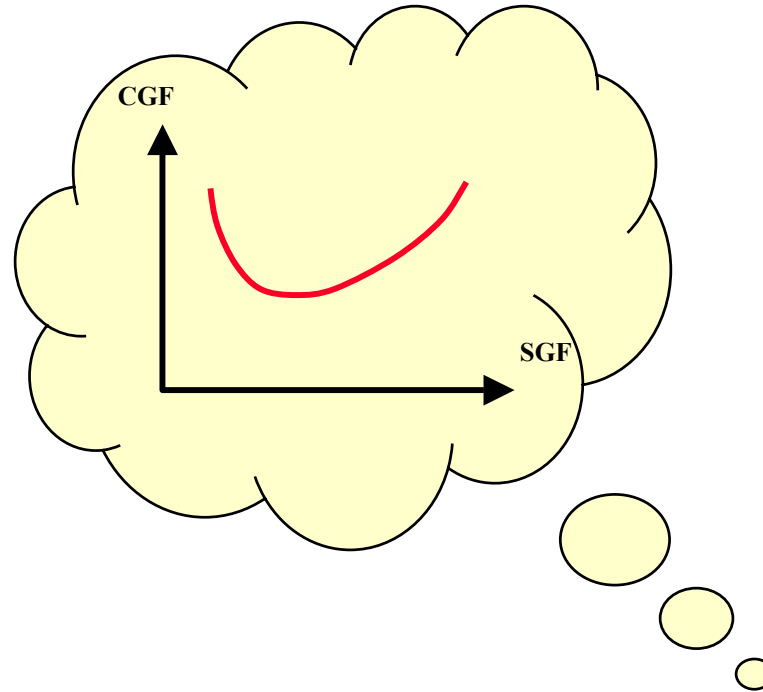


The gentle rise here conforms with the near-critical test statistic

SGF after CGF Sort

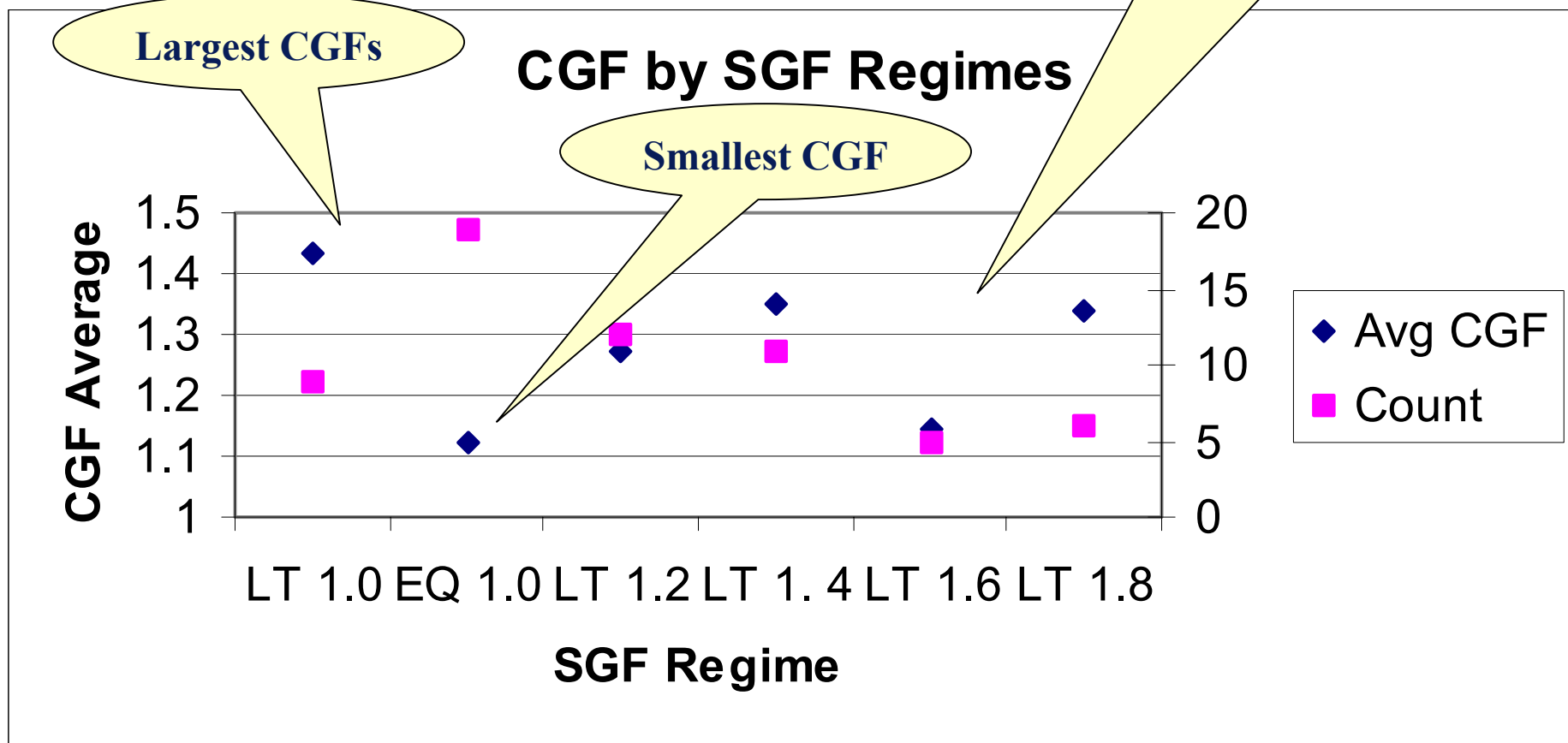


There is no *strong* rising pattern in either CGF or SGF after sorting on the other



# Investigating the Hypothesis

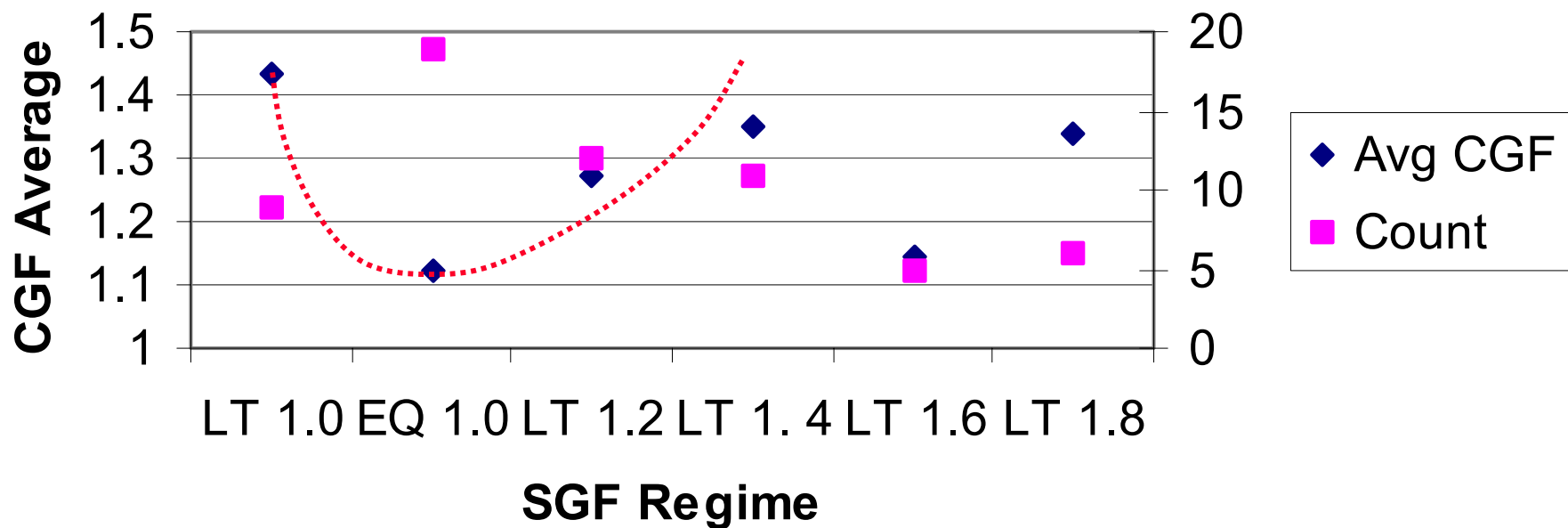
# CGF by Regime



Programs divided into SGF Regimes show a marked pattern, like the hypothesis suggested

# CGF by Regime

## CGF by SGF Regimes



Programs divided into SGF regimes look somewhat like the hypothesis suggested they would

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# Normalizing for Dollar Size

## *To Remove Inadvertent Dollar Size Distortion*

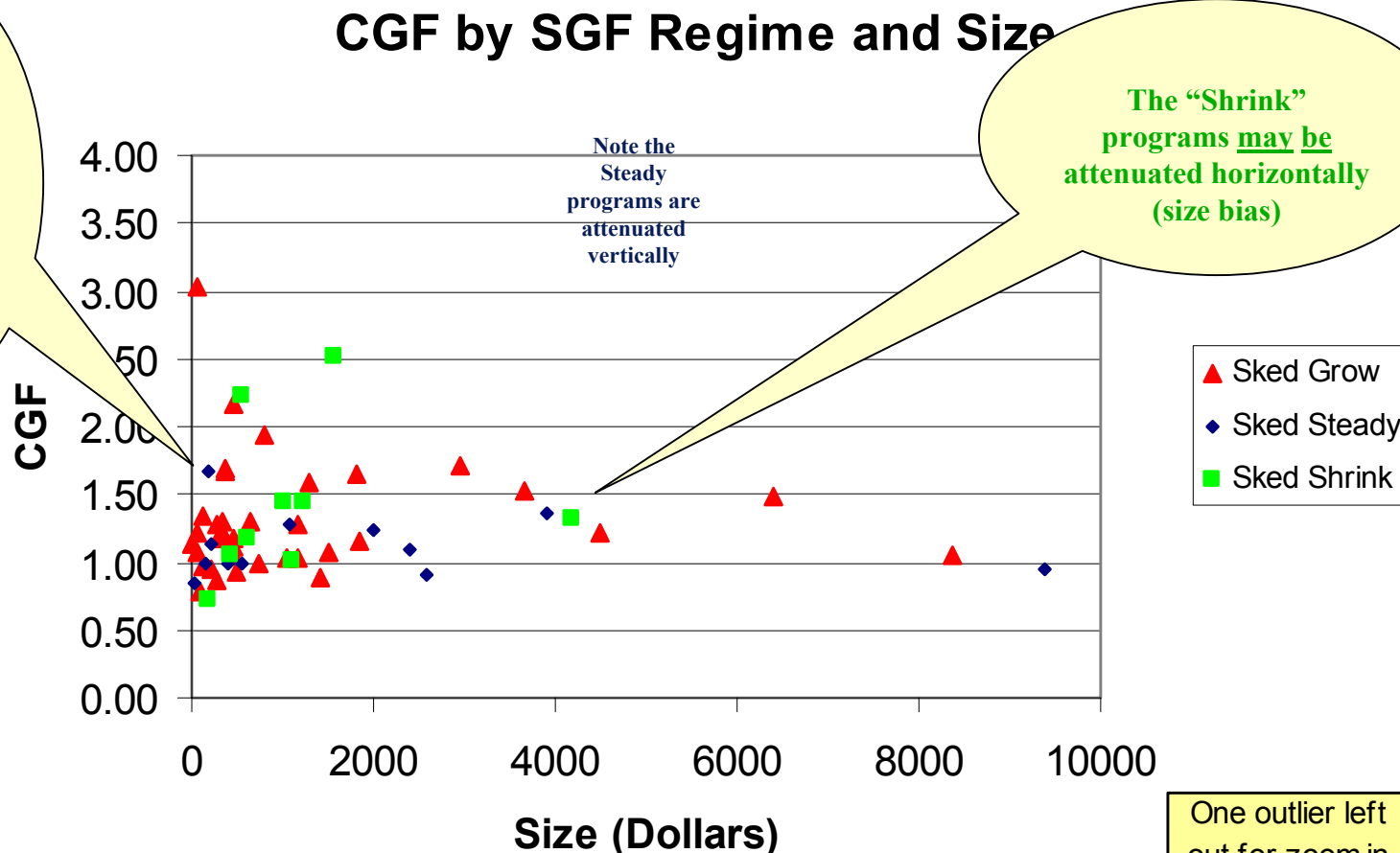


# Size Normalization

- We know there is a size effect in CGF
- We think there is a size effect in SGF
- We must investigate schedule effects free from size effects
  - First we will look at a scatter plot
  - Then we will normalize<sup>1</sup> all programs for dollar size, and compare to actuals
    - If there is a pattern in any regime, we will worry
    - If there is no regime pattern, we can conclude there is no dollar size distortion
- We chose to correct out dollar-size because it is stronger, and because we were worried about a length and SGF correlation causing mischief if we tried to correct it out

<sup>1</sup> See backup for norming algorithm

# Is there a Dollar-Size Bias?



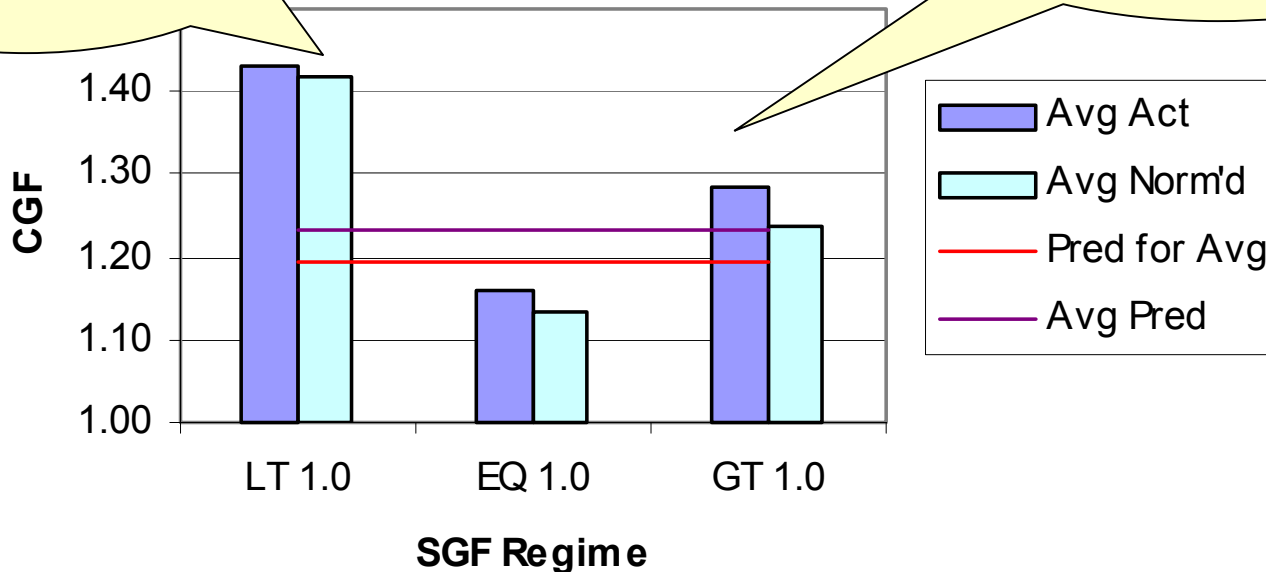
**Programs in the 3 regimes show no clear size bias, but a clear growth bias**

# Normed vs Actual CGFs by Regime

Note: the mean error of the predictions used for norming was 6%, further reinforcing the idea that the actuals were slightly above the predictions

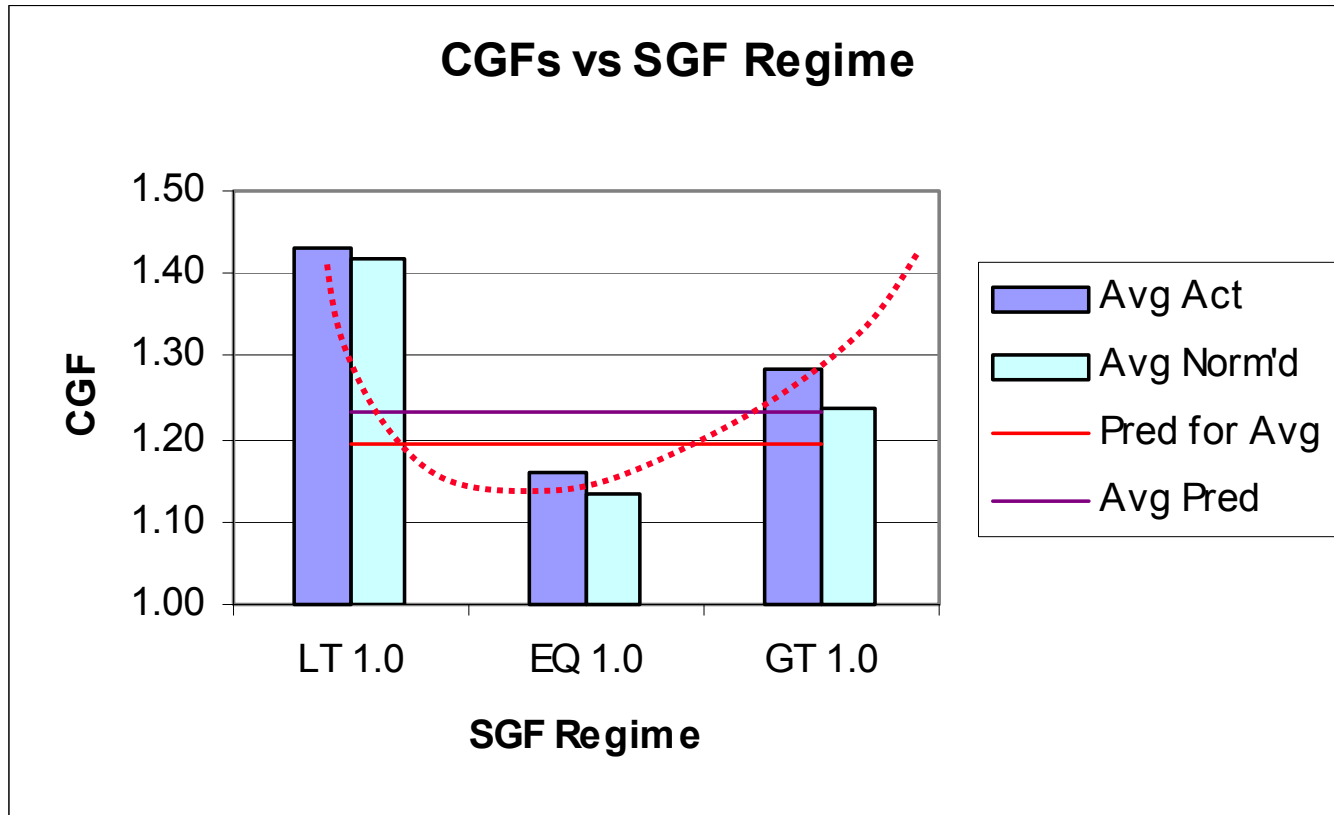
## CGFs vs SGF Regime

Normed averages are smaller, meaning that they had generally more growth than predicted



**Averages for size-normed programs show the same patterns, so there is no size distortion**

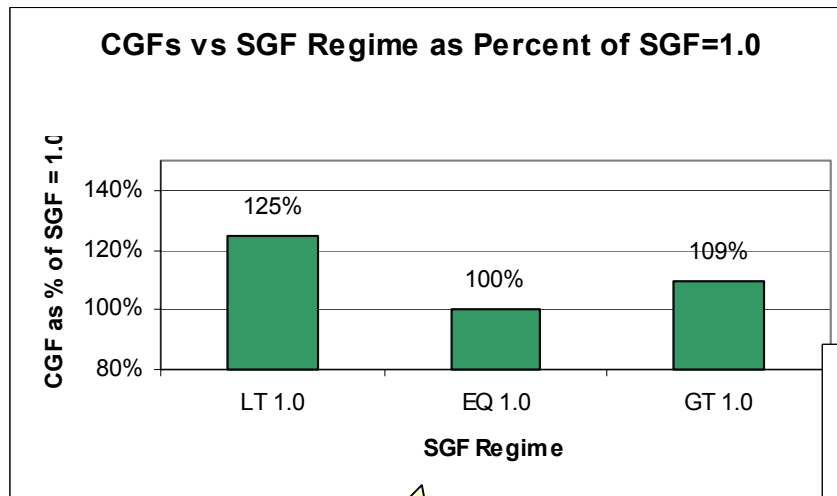
# Normed vs Actual CGFs by Regime



**Both sets of bars look like the hypothesis suggested they would**

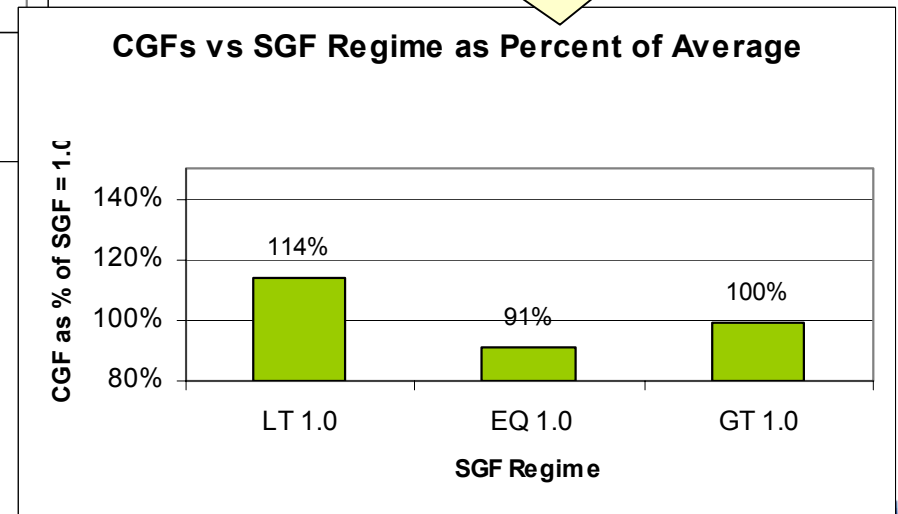
# Correction Factors

- We must correct for schedule growth, if we can predict it. The form of the prediction is unclear:



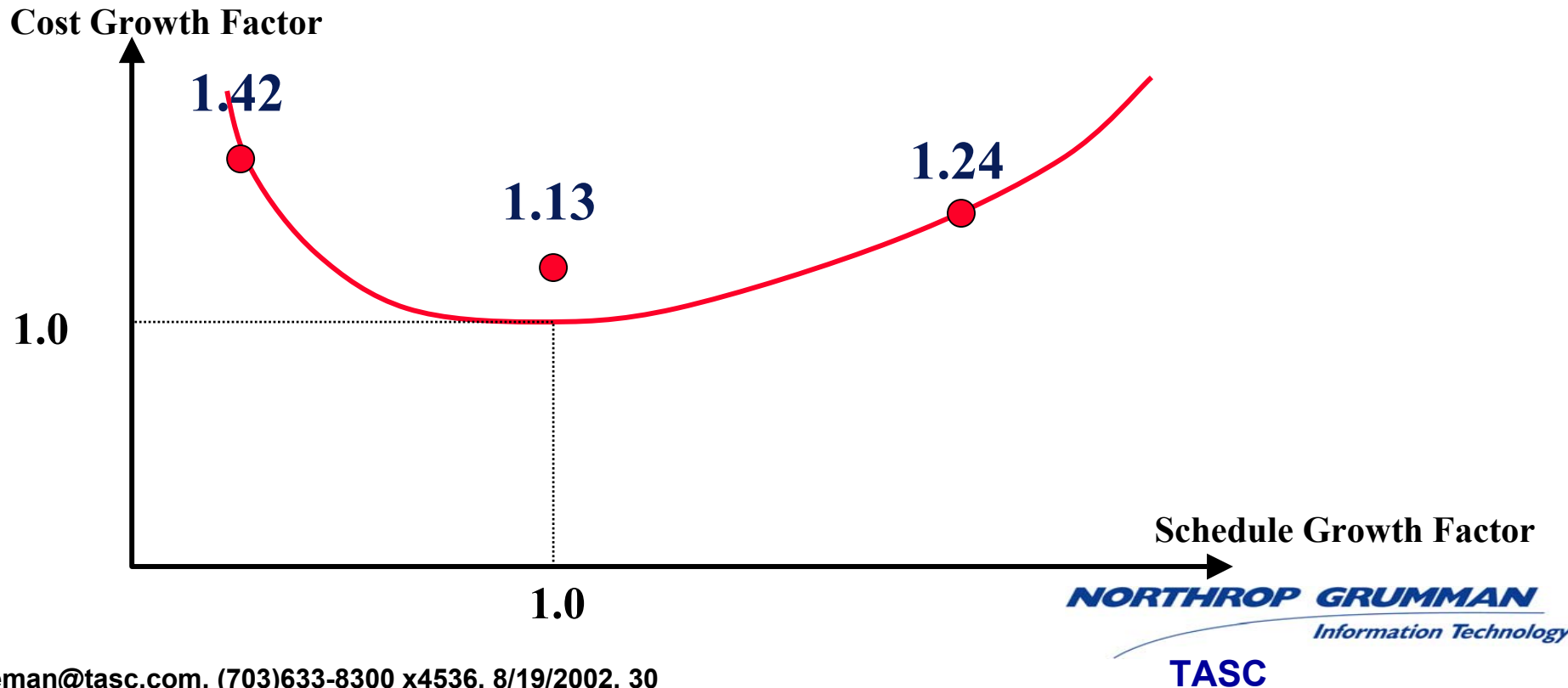
These factors describe what happens if schedules change

We might use these factors to correct nominal growth factors



# Hypothesis

- The Hypothesis was *about right*
  - The below is all we can say for sure
  - Some liberties have been taken with the graph



# Conclusions

- **Schedule growth is less extreme than cost growth**
  - But patterns are the same
- **There is a cost-size and length effect, just as for cost growth**
  - Dollar-larger programs lengthen less
  - Longer programs lengthen less
- **Neither cost nor length predict the other**
- **There is a difference in cost growth by schedule-growth regime**

<u>Regime</u>	<u>CGF</u>	Relative to <u>No Change</u>	Relative to <u>Average</u>
– Programs that shorten	1.42	1.25	1.14
– Programs that stay the same	1.13	1.00	0.91
– Programs that lengthen	1.24	1.09	1.00

**The hypothesis was essentially true**

# Backup



# Size Norming

- We occasionally wish to remove all size effects from CGF data. To do this we:
  - Predict the *expected* CGF using our cost-size equations (CGF\_Predicted)
  - Move all points to a specified nominal size by correcting them using a factor based on the CGF for the nominal size (CGF\_Nominal) based on
    - Their own average size
    - Some other average size, such as the all-DoD Average
- The norming equation is:
$$\text{CGF\_Normalized} = \text{CGF\_Actual} * \text{CGF\_Predicted} / \text{CGF\_Nominal}$$
- The result will be nominalized data free from any effects caused by cost size, and we can now look for other effects